Illinois State Geological Survey 1989-90
Science on Energy, Groundwater Protection

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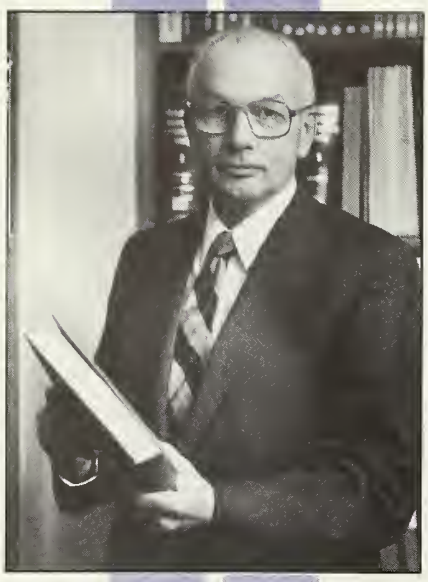


From the Chief

The Illinois State Geological Survey (ISGS), a division of the Department of Energy and Natural Resources (ENR), was formed by state statute in 1905 to study and report on the geology and mineral resources of Illinois. Being both scientific and informational in nature, the Survey has programs of research, data collection, public service, and education with two major goals: to strengthen the state's economy by encouraging sound exploration, logical development, and wise use of Illinois' mineral resources; and to improve the quality of life for residents by providing information useful in protecting or enhancing their well being.

Our efforts focus on the state's mineral resources such as coal, oil and gas, water, industrial minerals and metals; on matters related to environmental geology such as groundwater protection, pollution prevention and waste management, geological hazards, and engineering geology; and on basic scientific and general research required to support applied research programs. Being non-regulatory is essential in maintaining our credibility and reputation for unbiased, objective, scientific information required by others to develop sound environmental and mineral resource policies and decisions.

The Survey's extensive data base includes well records for more than 310,000 borings and files of earth samples representing more than 740,000,000 feet of drilling in Illinois and an industrial investment in the billions of dollars. Our aim in the acquisition and management of data is to provide a collection of useful, organized material, well maintained and readily accessible to the staff, other agencies, and the private and public sectors.

During the past year, our staff comprised 163 state- and 95 grants-and-contracts-funded scientists, engineers, and support personnel. With a multidisciplinary staff, an exceptional data base, and extensive laboratory and field capabilities, the ISGS is in a unique position to tackle a number of complex issues facing the state.

Major issues addressed during the past five years include those affecting:

Jobs and economic development assurance of employment and growth of Illinois' industries. Working closely with other state agencies, the Survey provided information about foundation conditions, water supplies, mined-out areas and other data to help bring the Chrysler-Mitsubishi plant to Illinois. Our scientists also sought ways to improve the utilization of the state's coal, helping mitigate the decline of employment in coal mining.

Energy adequate supplies of domestic gasoline, diesel, and heating oil for transportation and energy security. The ISGS is bringing federal matching funds from the U.S. Department of Energy (USDOE) in a $4.9 million, four-year program to help improve the amount of oil recovered from Illinois' existing fields.

Pollution prevention protection of Illinois' groundwater supplies and reduction of atmospheric emissions. Through a strong program of waste management research, the Survey assists municipal, county, and regional governments and state agencies in siting landfills, in monitoring and modelling the fate of contaminants, and in identifying areas susceptible to groundwater contamination. We are also actively engaged in finding ways of reducing sulfur in coal and sulfur dioxide in emission gases from coal-burning plants.

Minerals access to construction materials for rebuilding the infrastructure and to strategic and critical minerals to reduce this country's reliance on foreign sources. Our scientists have been involved in assessments of mineral potential and availability.

Water access to adequate supplies of clean groundwater. Using sophisticated geophysical techniques, the ISGS, in cooperation with the Illinois State Water Survey (ISWS), helped a number of communities and farmers locate water supplies.

Land its wise use. Our scientists mapped the geological resources and natural or man-caused geologic hazards in several counties. Then, using the capabilities of the Illinois Geographic Information System (IGIS), they helped regional and local governments and industry formulate plans for land use.

Facilities and infrastructure the need for information to site facilities and rebuild existing infrastructures. The Survey works with the Illinois Department of Transportation (IDOT) to identify geological and man-caused environmental hazards that must be considered in property acquisitions and highway construction projects. The geological picture developed for the Superconducting Super Collider effort received outstanding marks from the USDOE.

Agriculture protection of prime farmlands. Together with the Farm Bureau, the Department of Mines and Minerals and the Coal Association, the ISGS directs a program to develop guidelines that will protect prime farmlands while maximizing coal production.

Public safety and health identification and minimization of geologic risks. Staff of the Survey works with the Illinois Emergency Service and Disaster Agency on earthquake preparedness; with IDOT, the Department of Conservation, the U.S. Army Corps of Engineers, and the USGS on causes and means of avoiding coastal erosion along Lake Michigan's shoreline; with communities and others on landslide identification and protection; and with insurance companies on mine subsidence, a man-induced geological hazard.

This annual report, the third to be prepared especially for the general public, has two focuses: our research on waste management and prevention of groundwater pollution, and efforts on behalf of energy resources and uses. For a more inclusive look at the ISGS' research and service pursuits, please request a copy, free of charge, of the "Illinois State Geological Survey: Science focusing on issues and trends; future needs" published in 1990.

What's put in and on the land can affect our water

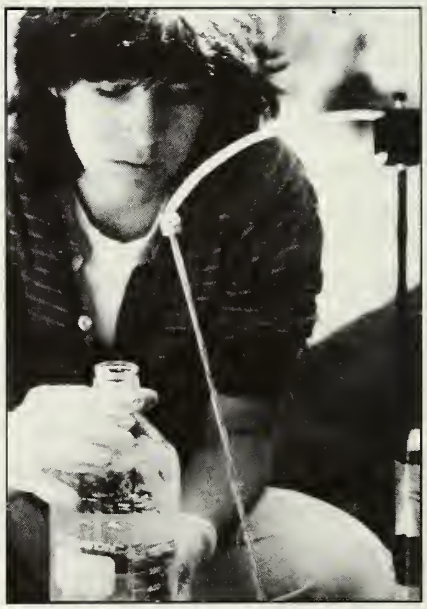
Even the earliest inhabitants of this state were challenged by environmental problems. They contended with food shortages and contamination from wastes, handling these issues in a simple, straight forward manner--packing up and moving on.

As Illinois' population grew and the way of life became more complex, environmental concerns intensified along with competition for the land available in the region. One can no longer move on, unconcerned about natural or man-caused environmental problems.

For instance, two closely related concerns--groundwater protection and waste management--have garnered local, statewide and national attention. Regardless of methods used to reduce the amount of waste generated, a residual will always remain that must be disposed of by burial. Thus, the proper handling and disposal of wastes will remain an issue, not only for Illinois but the nation as a whole. The legacy of past improper practices of waste disposal includes numerous sites that have adversely affected the environment...contaminating soils and groundwater, making them virtually unusable without costly clean-up procedures.

Landfills are not the only potential cause of groundwater contamination, however. In recent years, attention has been drawn to non-point sources of contamination such as agricultural chemicals. These chemicals are not considered wastes by the users, but if the chemicals are not entirely consumed by crops, they may infiltrate an aquifer and contaminate groundwater.

The Geological Survey has a mission to perform hydrogeologic investigations that support groundwater protection and resource programs. These studies give insights into pathways of subsurface fluid movement and how and when groundwater resources should be protected. Major efforts are concentrated on projects to meet the mandates of the Illinois Groundwater Protection Act (IGPA), including cooperative projects involving the ISWS and the Illinois Department of Agriculture (IDOA) that have focused on agricultural chemicals and ground-



Mary Greenpool, assistant staff geologist, Groundwater Protection Section, takes a sample of water from a well for a pilot study of agricultural chemicals in five representative hydrogeologic settings.

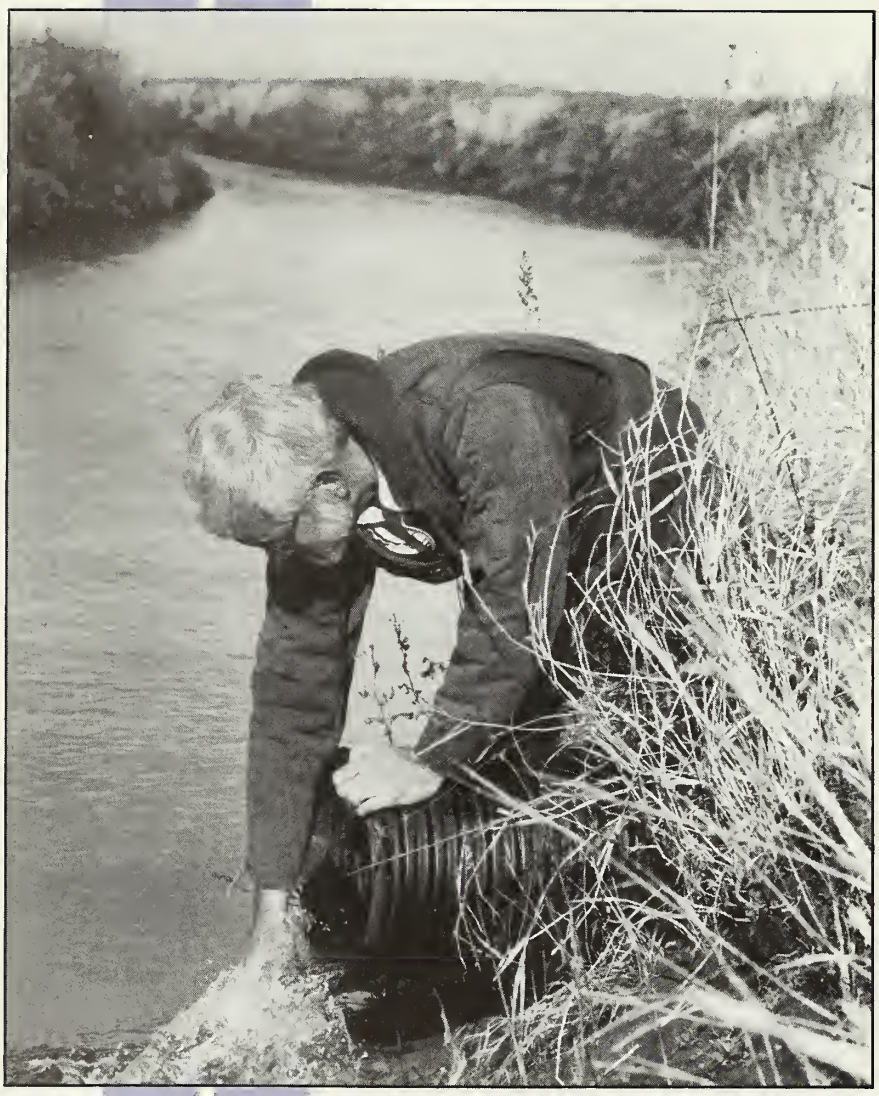
water quality. Future work for groundwater protection will concentrate on developing methods for county and municipal hydrogeological mapping, enhancing studies of agricultural chemicals in groundwater, and cooperating further with state and federal agencies interested in joint groundwater protection studies.

One such joint pursuit arose in response to a national priority to identify and evaluate groundwater resources that may potentially become contaminated. Through this effort, the ISGS is cooperating with the USGS to develop a method to help assess the contamination potential of aquifers on a multistate basis. Evaluating the texture of surface sediments, permeability of the bedrock directly beneath surficial deposits, presence of aquifers, and thickness of surficial deposits, scientists have been able to compare hydrogeologic settings according to their relative degree of susceptibility to contamination. As an outgrowth of this cooperative effort, the USGS will produce a contamination-potential map covering parts of Illinois, Indiana, Ohio, Michigan and Wisconsin.

Funded large-scaled mapping needed

Offering a bench mark on groundwater protection programs throughout the state and plans for the future, the Survey prepared a briefing paper, including specific examples of geologic mapping, assessments of water quality and quantity, and technical assistance programs. The document highlights the need for unified, systematic, large-scaled mapping and assessment of groundwater resources since most studies in Illinois have been regional investigations or specific to a need.

During the year in review, a number of groundwater protection studies have been looking at the contamination issue of pesticides and agricultural chemicals. In a February 1990 report to the Illinois General Assembly, the Geological Survey and ISWS presented an initial evaluation of the potential impact of agricultural practices on groundwater quality; made recommendations--changes in practices of selecting and applying pesticides, applying nitrogen fertilizer, and rotating crops--to minimize impacts; and summarized previous studies to assess the effects of pesticides on groundwater quality in the state. Although samples in Illinois and other midwestern states showed that shallow aquifers are vulnerable to contamination, data were insufficient, according to the report, to accurately determine the impact pesticides have had on the quality of groundwater.



Dennis McKenna, associate geologist in the Groundwater Protection Section, takes a water sample from a farm tile for a study to determine groundwater contributions to atrazine loadings in streams.

Other investigations take up the point of quality such as the cooperative program among the ISGS, the IDOA and the U of I's Extension Service to sample more than 400 randomly-selected wells to provide the first statistically-valid statewide estimate of the occurrence of agricultural chemicals in rural private wells. A related pilot study, in cooperation with the Water Survey and IDOA, is determining whether specific geological areas of the state are more vulnerable to contamination than others. By field testing and evaluating various components of the experimental design proposed for a statewide survey of agricultural chemicals in rural private wells in Illinois, the project will provide a preliminary assessment of the occurrence of agricultural chemicals in such wells in five representative hydrogeologic settings in the state.

In related work, the Survey is mandated by the U.S. Environmental Protection Agency (USEPA) to provide technical assistance to the IDOA in developing a strategy for managing the use of pesticides to prevent groundwater contamination. The plan emphasizes groundwater monitoring and differential protection of groundwater based on vulnerability to contamination.

In yet another pesticide-detection project, water samples from drainage tiles, soil-water samplers, and groundwater monitoring wells continue to be collected and analyzed for several of these substances. An evaluation will be made of the relationship between concentrations of drainage-tile effluent and shallow groundwater for the Water Resources Center at the U of I, which funded the study.

Potential leaching from the composting of yard wastes were also investigated with funding from the Center for Solid Waste Management and Research at the U of I. Scientists found that the mobility of the degradated chemicals into groundwater or onto crops used for human consumption will be controlled, in part, by differences in soil compositions. They concluded that residues should be monitored at a controlled location, but such monitoring data currently are lacking for most chemicals expected to be generated from composted yard wastes.

Contamination from tanks considered

Leaking underground storage tanks present another major contamination factor for consideration. Two regional studies included the automation of location data of 546 underground storage tanks for petroleum products located within the Illinois Environmental Protection Agency's (IEPA) Regions 1 and 2, a 21-county area in northern Illinois. A model of the vulnerability of shallow and deep aquifers to contamination from surface and near-surface sources of waste, developed by the Survey, was used to rank the relative contamination potential of tank locations. These rankings and the proximity of the tanks to known private, public and industrial wells were weighted and prioritized by a consulting firm to determine the order in which the IEPA should investigate these sites for remediation.

Because of public opposition, siting new municipal landfills has become very difficult. Concern about groundwater contamination, an issue for decades, was the impetus for a comprehensive analysis undertaken of the scientific literature summarizing past experiences with municipal landfills and future expectations. The study found few case histories in which municipal landfills seriously contaminated groundwater, but the majority of active landfills did not have any type of groundwater monitoring program. Most problematic landfills were located in geologically unsuitable areas, constructed without an effective liner, or poorly operated, according to the literature. While proposed regulations may mandate the use of soil liners, leachate collection systems and final covers, evaluations of these requirements were sparse. The literature pointed to on-site expansions and landfill mining as short-term remedies to the landfill crisis.

Other research quantitatively ranked several mapped hydrogeologic scenarios common to Illinois for the potential for groundwater contamination attributable to burying municipal wastes. In addition, researchers determined that the Illinois Pollution Control Board's (IPCB) proposed groundwater compliance distance of 100 feet as the maximum for leachate migration from municipal landfills may be appropriate.

Transit time through compacted clays of a prototype liner for landfills showed the movement of water (hydraulic conductivity) significantly lower than the maximum allowed by the USEPA. The study, which began in 1985 and is the only ongoing one of its type in this country, uses an 8-by-15-by-0.9-meter clay liner ponded in April 1988 with 30 centimeters of water. After two years, the wetting front had penetrated to between 40 and 50 centimeters with breakthrough of the tracers estimated between four and six years. The liner's performance is being monitored with 218 instruments.

While Keros Cartwright, principal geologist and head of the Hydrogeology Research Lab, tops off water in an evaporation pan at the clay liner, Ivan Krapac, staff geochemist in the Geochemistry Section, notes the activity.

A manuscript, "Infiltration Measurements of a Field-Scale Soil Liner: Preliminary Results," describes the results of two years of infiltration measurements and relates experiments conducted at the liner. The data show the liner successfully achieved the USEPA's criterion for a low saturated hydraulic conductivity, hydraulic properties of the liner are homogeneously distributed, and water probably will not come through the bottom of the liner until April 1992.

A second paper, "Fluctuations in the Measurement of Water Infiltration into a Field-Scale Soil Liner," describes the effects of construction and changes in pond level and barometric pressure on the infiltration of water into the liner. Data from laboratory experiments will be incorporated into the manuscript.

Research benefiting waste management has been a program of this Survey for many years. Areas of concentration include technical assistance to counties on solid waste issues, characterization of low-level radioactive waste (LLRW) sites, and deep-well injection of waste.

With Lisa Smith, assistant staff geologist, Computer Research and Services Section, the middle of three persons looking on, exploratory boreholes are drilled to look at the geologic sequence at one of two candidate sites being evaluated for a landfill out of 33 possible areas identified on maps produced by the Section for Champaign County's Intergovernmental Solid Waste Disposal Association. These maps portrayed the distribution and thickness of the major aquifers in the county and illuminated areas generally suitable for further evaluation for landfill siting.

Pathways for fluid movements studied

In areas of its expertise, the ISGS is responding to issues regarding the relationship between waste disposal/management and geology/hydrogeology. By communicating with and cooperation from private consultants, developers of waste disposal facilities, and other state agencies, the Geological Survey works to ensure a solid understanding of the geology of existing or potential waste sites and the pathways for fluid movement, seeking to provide scientific information useful in problem resolution and decision making.

A county assistance program began in 1990 to provide geologic mapping and screening, using the computerized IGIS, for areas in which solid waste siting is of immediate concern. Funded by the Office of Solid Waste and Renewable Resources (OSWRR) of ENR, this project offers technical assistance to county and municipal governments in screening their areas for potential sites for solid waste disposal. This detailed mapping effort is designed to compliment an initial countywide IGIS screening being performed by ENR's Office of Research and Planning.

Besides meeting with officials from Whiteside, Madison, Lake and Sangamon counties to discuss landfill and other siting needs for solid waste, the Survey's staff continued to assist Champaign County with screening for a landfill site. Concluding the 12-month project, the ISGS presented the Champaign County Intergovernmental Solid Waste Disposal Association (ISWDA) maps that identified the distribution and thickness of the major aquifers in the county and illuminated areas generally suitable for further evaluation for landfill siting.

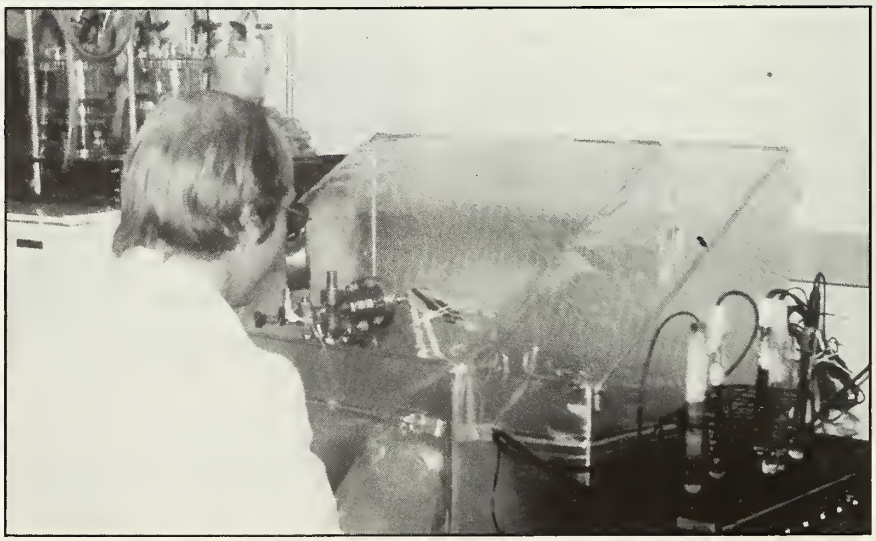
The county assistance program has also been extended to Lake County. This county has an immediate need to identify sites for two sanitary landfills (one for general refuse and the other for

A sample of hazardous waste and material from a typical subsurface formation into which the waste is injected is being inserted into a pressure vessel for pressurization and heat treatment.

construction wastes) and six composting facilities.

In the area of hazardous wastes, the General Assembly mandated the ISGS and ISWS to study and report on the state's underground injection control (UIC) program, provided in testimony to the IPCB and a final 1989 report, "Evaluation of Underground Injection of Industrial Waste in Illinois." The Geological Survey continues to provide technical expertise in and advice on the UIC program to the IEPA and the USEPA, Region V. Besides reviewing permit applications and modifications, monthly operating reports, and other related technical documents pertaining to the hazardous waste injection wells, scientists review the local and regional geology and hydrogeology of these sites. A computerized data base to facilitate the review process is being developed.

In underground injection, liquid wastes are placed into geological formations. Geochemical reactions between the wastes and receiving formation may determine whether injection at a specific site can be viewed as a waste storage technique or a waste treatment approach in which the liquid is transformed into a nonhazardous waste. Predicting these chemical



Simulating subsurface conditions, these laboratory samples are then opened in a nitrogen (glove box) environment to study geochemical transformations.

reactions is important to ensure that injection is protective of the environment. In a laboratory study, samples of two waste streams (a highly alkaline, brine-like solution and a dilute hydrochloric solution), collected at injection facilities in Illinois, were mixed with ground core samples of injection formations and held for 155 to 230 days under constant temperature and pressure. The acidic waste was neutralized by carbonate dissolution, whereas the major-element composition of the alkaline waste was not altered. Although a computer-assisted thermodynamic model accurately predicted the presence of some reaction products, the data base needs to be expanded for these predictive calculations.

Preparing to do radiocarbon dating of groundwater, Jack Liu, senior staff geochemist and supervisor of the Isotope Geochemistry Lab, is collecting dissolved carbon dioxide from a water sample.

Technical support given

Participating in the state's efforts to locate a LLRW disposal site, the Survey has continued its technical support on site characterization to Battelle Memorial Institute. During this period, scientists testified before the Senate Executive Committee investigating the siting process and attended numerous technical meetings to interpret data for Battelle and its contractors working on site characterization. Besides reviewing information from siting contractors at the candidate sites at Martinsville and Geff and the geologically-oriented portions of the site-characterization document, the Survey submitted its report to Battelle on the glacial geology of the Martinsville site.

As part of the LLRW site studies, the Isotope Geochemistry Laboratory has been designated the primary lab for radiocarbon (Carbon-14) dating of groundwater at both locations. Ages up to 45,000 years can be determined for groundwater by measuring the concentration

of Carbon-14 in the inorganic fraction of carbon contained in the water. Being their first groundwater-dating project, scientists developed and tested many new procedures and ascertained 41 Carbon-14 dates on groundwater, methane and soil-gas samples from the Martinsville and Geff sites. Preliminary results indicate that by analyzing both the water and dissolved gases, researchers can correct for the influx of carbon dioxide from the decay of buried organic matter, thus expanding the usefulness of radiocarbon dating of groundwater in glacial deposits.

In conclusion, water, a necessity for all living things, is a very vulnerable resource and must be protected from contamination. Thus, the ISGS is very actively involved in meeting mandates of the IGPA by conducting pertinent mapping, assessments, monitoring and technical assistance programs in support of protection and preservation of groundwater quality as well as management of groundwater resources. To facilitate these tasks, the Survey has been involved in programs that provide information to state and county agencies that begin the process of groundwater protection.

Closely tied to groundwater protection is waste management, the practices and technology of which will continue to attract researchers' efforts and interests. Illinois ranks second in the country in the production of hazardous wastes, much of which is generated in northeastern Illinois, an area not unlike the remainder of the state wherein residents are resisting new landfills and expansions to those nearing capacity. Notwithstanding, proper handling and disposal of waste is a concern, locally, regionally, statewide and nationally.

Leaders of a field trip to provide members of the Champaign County Intergovernmental Solid Waste Disposal Association (ISWDA) a basic introduction to glacial geology are from the left Myrna Killey, associate geologist, Environmental Studies and Assessment Section; John Kempton, geologist and head of the Quaternary Framework Studies Section; Don McKay, geologist and head of the Computer Research and Services Section; and Brian Trask, associate geologist, Environmental Studies and Assessment Section. Some 20 members of the ISWDA attended the event which highlighted the geology of the county and factors important to siting a landfill, including the sand and gravel, glacial tills and glacial moraines.

In this regard, the ISGS has conducted field and laboratory studies since the early 1960s on such subjects as groundwater flow and transport of groundwater contaminants, chemical interaction of contaminants with earth materials, and improvements in the construction of landfill trench covers and liners. The Survey's waste management research and service work has two major thrusts: site-screening and characterization studies for proposed waste disposal facilities, and more generic studies that relate to the movement of chemicals in the subsurface and the ability to monitor this movement. On the basis of these research programs, the ISGS provides geological information about waste disposal problems for other governmental agencies, industry and the public.

While appetite for energy is ever greater, the domestic supply is down

When the Arab oil embargo was imposed in 1973, the United States was importing nearly six million barrels of oil a day. Just prior to the Iraqi invasion of Kuwait in August 1990, this country's imports had risen to almost eight million barrels a day, yet domestic production had declined by nearly two million barrels a day since 1985. In fact, imported crude oil and crude oil-based products supplied 50 percent of total U.S. needs for the first seven months of 1990, up from 31.5 percent in 1987. If the trend continues, oil imports could increase to between 60 and 70 percent of total domestic consumption by year 2000.

The Middle East Crisis has drawn attention to one of this country's top energy problems--the inadequate supply of domestic petroleum for transportation fuels. While the world currently has more than adequate oil reserves, the present surplus must be viewed as temporary: World supplies must decrease as oil is a non-renewable resource. At home, the domestic supply of crude oil is seriously declining while U.S. demand is increasing. Proven U.S. oil reserves are only 3.7 percent of the world's total.

Since the worldwide oversupply of oil led to a price collapse in 1986, exploration for oil and gas in the United States and marginal production of this commodity have been sharply reduced. Some 'stripper' wells, producing less than 10 barrels a day, have been abandoned as income did not support continued costs of operation. (About 14.5 percent of the nation's production and more than 95 percent of Illinois' production come from such wells.) Although recent price increases, attributable to the Middle East conflict, will doubtless encourage renewed exploration of and production from smaller fields heretofore considered marginal to non-commercial, the result of low-priced oil has been a widening gap between U.S. consumption and production.

This gap, which had narrowed in the late '70s and early '80s, is predicted to widen further. To meet the nation's needs, the country has increased its oil imports, having a negative impact on the nation's balance of payments, security of petroleum supply, and ultimately, national security and defense needs. As imports increase and the world's excess capacity is reduced, OPEC, with the majority of the world's reserves, will gain a greater share of the market.

The economic impact of low prices on the state's oil industry has been severe. Oil prices in Illinois decreased from an average of $35.00 a barrel in 1981 to $18.28 in 1989. The price in the Illinois Basin was $16.50 per barrel in mid July 1990 until the Middle East conflict resulted in oil-price gymnastics. Prices rose to $39.25 a barrel in the second week of October and closed the year at $25.75 a barrel. During the period of low prices, the state's crude oil production in 1989 was 20.4 million bar-

rels, the lowest total in 50 years. Permits to drill dropped 21 percent in 1989 relative to 1988. Activity declined as a function of low oil prices. Illinois' oil and gas industry remains economically depressed, a state expected to continue until prices stabilize at an acceptable level, leading to additional activity.

Research and development hindered

The downturn in the oil industry has severely curtailed research and development (R&D) nationwide in oil and gas. The ability of major oil companies to conduct the wide-ranging research of earlier years has been curtailed, and thousands of smaller independents and operators cannot support their own research effort. More than 99 percent of the companies which produce oil and gas in the state are independents; they account for 66.75 percent of Illinois' production.

Both the state and federal governments are taking steps to carry out research activities, especially with respect to the needs of smaller companies that own and operate a large proportion of the wells and oil fields in this country. One of the chief research targets is to find ways to locate and profitably produce the more than 90 billion barrels of unswept, by-passed oil-in-place in already discovered reservoirs. Some 1.5 billion barrels of this "discovered" oil is in Illinois, the eighth ranked state in this category in the conterminous United States.

Technology transfer is under way as Rick Rice, assistant staff geologist, Oil and Gas Section, at right, discusses with guests the detailed study before them of the Stewardson Field to determine the variability in the distribution of oil in that field and the potential for strategic infill drilling.

Dick Howard, geologist in the Oil and Gas Section, compares core samples to an electric log of the same interval of rocks, trying to find clues to the depositional environment that affects porosity and permeability.

With foresight to address concerns over the U.S. energy problem, the state and the USDOE adopted an Annex in 1989 to their existing Memorandum of Understanding (MOU), encouraging cooperation on a number of energy-related subjects, including oil and gas. The ISGS and ENR have secured funding for a DOE oil and gas initiative as part of an active fossil-fuel research program to improve oil production in Illinois. This four-year oil research activity received an initial award of $1.5 million in 1989 and $1.3 million for 1990, shared equally by the state and federal governments. Ongoing state support will need new legislation in 1991, and additional contracted U.S. support beyond 1991 will require stable state funding as a match to cover this research that seeks to increase the supply of domestic hydrocarbons in Illinois.

Although the state continues to produce some 20 million barrels of oil a year, about two-thirds of the discovered oil remains trapped within reservoirs. Much of the oil that is not produced by primary and secondary (water flood) recovery methods is either left in the pore spaces of rocks because of inherent forces and interactions between the rocks and their contained fluids or because of by-passing that results during producing operations. In addition, many wells initially producing hundreds of barrels of oil per day decline to less than 10 barrels a day, attributable in some cases to formation damage, making wells uneconomical and discouraging investments.

Through its cooperatively funded effort, the ISGS has expanded its program of research and service in oil and gas to define Illinois' remaining unswept mobile oil, develop technology to enhance production from mature fields, cultivate incentives to encourage exploration, promote wise development of the state's oil and gas resources, and provide more complete and timely information to the oil industry. While the Survey hopes to persuade stripper-well

operators not to abandon their wells and thus cut off access to remaining oil in place, it also hopes to prove that future reserve additions can come from extensions to existing fields through geologically-targeted infill drilling. The program also aims to aid the petroleum industry in exploration and development of the state's resources by providing comprehensive data, mapping, and information from subsurface stratigraphic research on possible new petroleum targets and new techniques for exploiting existing fields and plays.

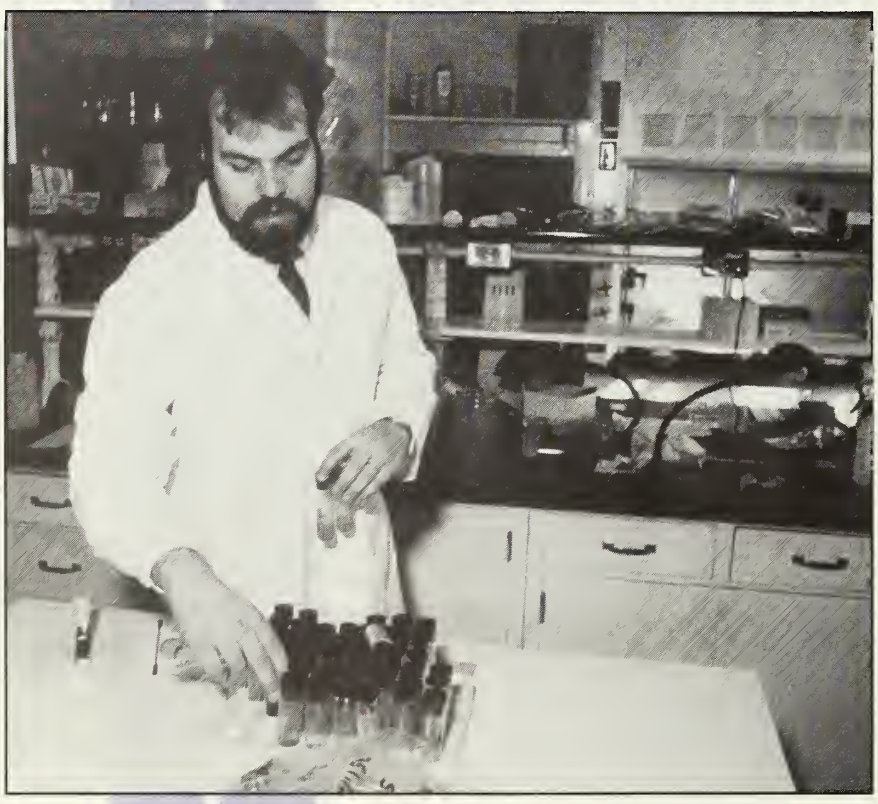
Checking a computer-generated geological map being printed on the electrostatic plotter is Stephen Whitaker, associate geologist, Oil and Gas Section.

Methods geared to Illinois' fields

This research thrust in improved and enhanced oil recovery is geared toward determining which methods of improved recovery work best for the variety of conditions existing in Illinois' oil fields. Research is required on new methods of improved recovery, including well completion/stimulation practices, and recovery processes using fluids and gases compatible with the reservoir, field, and rock properties. The method used to remove the remaining oil needs to take into account the geometry and heterogeneous nature of the reservoirs. The ISGS' expertise and equipment has positioned it to characterize the nature of oil and gas reservoirs in the subsurface and to improve the knowledge of subsurface petrophysical and geochemical conditions controlling fluid movement and, therefore, recovery of oil in the state's reservoirs. Already, significant differences in clay content, types of clay minerals, and cementing minerals have been discovered that affect the productivity of wells and, therefore, should influence completion practices.

To deal with reservoir characterization in Illinois, the Survey assembled an integrated, multidisciplinary team of geologists, reservoir engineers, geochemists, clay mineralogists, computer experts, and an economist who developed a plan to identify and assess significant types of oil reservoirs and will analyze selected reservoirs using advanced techniques. Thereafter, this team will provide outreach programs and workshops to encourage the state's producers to apply promising techniques in drilling and completing reservoirs. One of the products of this effort will be an Illinois-specific compendium of treatments for each of the reservoirs studied.

Scott Beaty, assistant staff geologist, Oil and Gas Section, prepares rock samples for X-ray diffraction to determine the kinds and relative quantities of clay minerals.



Twelve reservoirs producing from the Aux Vases and Cypress Sandstones—two of the most prolific oil-bearing units in the state—are being studied. Heterogeneities that control or limit fluid-flow behavior in these reservoirs are now being identified; this essential step is critical to developing techniques to maximize the recovery of hydrocarbons.

The effects that some commonly used chemical additives have on the permeability of the Aux Vases and Cypress Sandstone petroleum reservoirs are being investigated using core-flow research. Untreated oil and brine from oil wells in these two sandstones are used to simulate field conditions, allowing scientists to compare the effects of different additives on core samples.

Knowledge of formation-fluid chemistry can be used in under-

standing the lithological and hydrological conditions of reservoir rocks. Chemistry of these reservoir fluids and those being injected coupled with the mineralogical data can be used to predict changes in mineralogy, porosity, and permeability of the reservoir rocks during enhanced oil recovery techniques. Brine and oil samples collected from wells in eight fields producing from the Aux Vases and Cypress formations were analyzed for their chemical compositions and attributes. For clay and bulk mineral analysis, samples taken from whole and reduced core as well as core plugs from oil fields in the two formations were analyzed to establish the impact of mineralogy on reservoir behavior.

Scientists are also looking at new exploration methods and concepts. Methods are being applied to differentiate physically deposited from chemically formed clays, the latter, indicative of thermal conditions required for the maturation of hydrocarbons and of the nature of the movement and emplacement of subsurface fluids that also help to control the migration of hydrocarbons.

Investigations began on the mineralogical content of the Maquoketa Group shales, thought to be a potential source rock for oil, and the St. Peter Sandstone, which is equivalent in age and other characteristics to strata containing recent discoveries of natural gas in the Michigan Basin. Source-rock studies suggest that shales of the Maquoketa Formation in combination with sandstone beds in southwestern Illinois offer a potential source/trap play. The sandstones may also have served as potential carrier beds for hydrocarbon migration.

Dennis Haggerty, assistant staff petroleum engineer in the Oil and Gas Section, will learn the gas permeability of core he is loading into the core holder. Gas will be circulated through the core to measure its permeability or ability to allow fluids to flow through it. This information is used to determine oil production expectations from a given formation. Looking on is colleague Scott Beaty.

Producing zones identified

Electric well logs (continuous recordings of rock properties) from oil tests drilled before 1960 are being used to analyze the Aux Vases Sandstone reservoirs. Newly developed methods of using the old logs allow a quick and easy estimation of reservoir porosity and water saturation--key parameters in identifying previously unrecognized producing zones in older wells. Application of these methods is discussed in a new report published as ISGS Illinois Petroleum 134.

To expand the Survey's well data base system, data from 40,199 oil and gas wells in the state were acquired, validated, and transferred into the system. Data from some 13,000 holes drilled prior to 1915 also were entered. In addition, more than 25,000 water-well permits and logs were added using CONQuEST, the Survey's new data management systems, developed by the Well Data Base Unit.

Rick Rice looks over gas development maps.

Other oil-related information is available through 83 oil and gas development maps displayed in the Geological Records Unit. The status of individual wells and the geographical boundaries of oil and gas fields have been updated as of January 1990. Hand-drafted oil and gas development maps are being replaced by computer-generated versions, the first three of which will be available in Fiscal Year 1991.

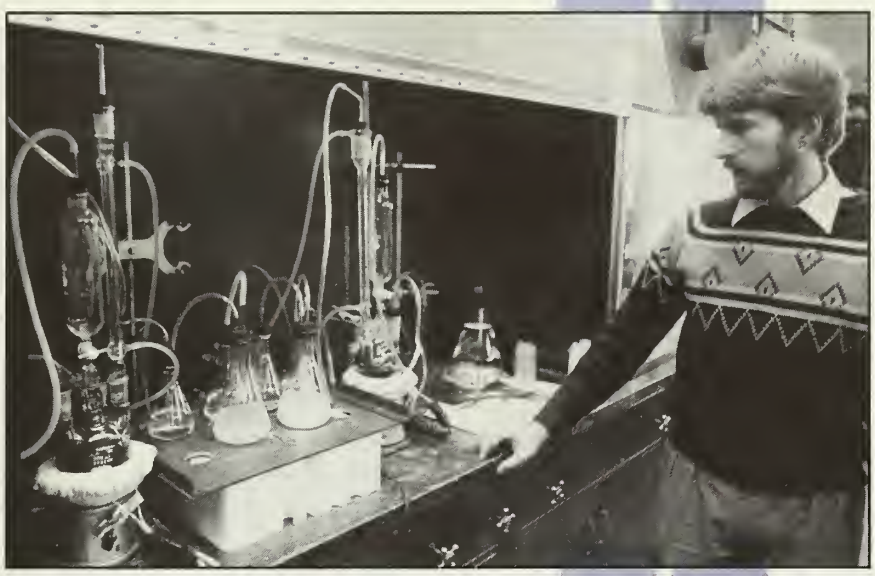
If successful, the "Improved and Enhanced Oil Recovery through a Reservoir Characterization Program in Illinois" will provide techniques to help maximize the recovery of hydrocarbons, leaving less oil behind, thus making more effective use of the state's natural heritage. Additionally, ideas and concepts may be introduced that serve as incentives for industry to explore for and produce more of the state's oil and gas. In effect, the ISGS is serving as a research arm for the smaller, independent oil producers who are unable to undertake their own research, yet produce much of Illinois' oil and gas.

The state's 1989 oil production of 20,400,000 barrels has a value of more than $372 million priced at $18.28 a barrel. If the application of technology developed during this program results in an increased production of 10 percent of the mobile oil left in reservoirs across the state, at $17.00 a barrel, the value of increased production in Illinois could equal $34.6 million per year.

Conservation could go a long way toward reducing America's reliance on foreign oil, but these measures won't be enough. While Americans' voracious appetite for energy has continued to grow, U.S. production of crude oil has declined and alternative U.S. sources of energy have not picked up the slack.... Nuclear energy, long hailed as the energy of the future, has hit a low in popularity in this

country as spent fuel rods pile up. Growing concerns about the cost of nuclear power plants along with the environmental impact of mining and processing uranium and disposal of nuclear waste have prompted utilities to move very slowly with further construction plans.... And coal, the world's second largest provider of energy, is facing costly, stringent environmental standards.

Other environmental concerns, many of which are as yet unquantified, are also affecting energy sources and supply. Sulfur dioxide, nitrous oxide, carbon dioxide, and particulate emissions from fossil fuels are being seriously questioned. The impact of alternative fuels on the environment will also require further research and scrutiny along with thorough investigations of relative efficiencies and costs of all fuels.



Keith Hackley, associate geochemist, Isotope Geochemistry Lab, separates different forms of sulfur from coal for isotope analysis which will determine their origin.

Coal shaped people, economy

In the meantime, Illinois leads the nation in bituminous coal resources that have a high potential for development. Throughout the state's history, coal has played a major role in shaping the people and the economy. Approximately 12,000 persons are working to produce 60 million tons of coal in Illinois each year. Several times that number of jobs are created because of, and in support of, the coal mining industry.

Besides being a high-quality energy resource, the state's coal is located near many major markets, requiring short hauls, consequently less fuel, to transport it to the user. However, continued use of Illinois' coal by utilities, its major market, is threatened by acid-rain-reduction goals which restrict sulfur emissions.

The state's coal currently emits, on the average, five pounds of sulfur dioxide per million Btu. New acid-rain-reduction goals will require decreases to 2.5 pounds of sulfur dioxide per million Btu by January 1995 and to 1.2 pounds, by January 2000. Achieving these goals will not generally be an easy task, even though coal-cleaning and emission-reduction programs are well established at state-funded research facilities, including the ISGS. These programs include research to decrease the sulfur and mineral-matter content (precombustion cleaning), research to more economically remove sulfur dioxide from combustion gases (post-combustion cleaning), and programs to encourage and aid researchers throughout the world to help solve problems associated with the use of Illinois' coal.

Precombustion cleaning is focused on removing sulfur and mineral matter before coal is burned to avoid removal of sulfur dioxide and ash from combustion gases. Physical cleaning alone, extracting the pyrite (inorganic sulfur) from coal, will generally not remove enough sulfur to com-

pletely avoid the need for extraction of sulfur dioxide from combustion gases. Sometimes one-half or more of the sulfur is organic (chemically attached to the coal) and not removable by physical cleaning measures. To remove organic sulfur, chemical methods, which break the sulfur/carbon bonds, are required. The ISGS has been involved in both physical and chemical methods to remove sulfur.

In physical cleaning, the Survey has worked to improve procedures for coal preparation plants to recover cleaner coarse coal, recover fine coal from preparation plant waste, grind coal and subsequently remove mineral and pyrite impurities, enlarge particle size to make coal agglomerates more transportable, add sulfur sorbents and/or binders to improve the strength of coal agglomerates and help them burn more cleanly, and leach chlorine and alkali salts from coal.

One of the Survey's physical cleaning processes, Aggregate Flotation, adds surfactants to conventional flotation reagent systems to promote the formation of microbubbles that attach to small coal particles to float them away from the mineral matter and pyrite. In tests up to 1,000 pounds per hour, these surfactants have increased flotation rates and decreased reagent requirements, potentially decreasing equipment and reagent costs. The ISGS' reagent system has effectively floated both finely-ground coal and natural fines from commercial preparation plants, allowing improvement of commercial flotation practices. However, transportation of such fine coal is more difficult.

Fine coal pelletized for transport

To overcome potential problems in transportation, the Survey is developing two size-enlargement technologies, one of which makes pellets from fine coal and a binder. These pellets have a high Btu value, lower sulfur content, and burning characteristics equal to or better than coal. The other size-enlargement process, using a sulfur-capturing sorbent such as lime hydrate, has potential for allowing many of Illinois' coals to be cleanly burned in fluidized-bed combustors or stoker boilers without further desulfurization equipment or procedures. Combinations of these two methods and physical coal cleaning could help bring nearly any of the state's coals into compliance with federal sulfur-reduction goals.

Carbon monoxide chemistry is used in two chemical cleaning efforts at the ISGS, one of which employs the gas to convert pyrite to a catalyst that is used to remove organic sulfur with ethanol. At the bench scale, this process has removed more than 90 percent of the sulfur from coal. Work during 1990 was carried out at a scale-up operation in an effort to process

Dave Moran, left, associate staff chemical engineer, and Mehrdad Lordgooei, associate staff mechanical engineer, Minerals Engineering Section, operate the batch hydrator, preparing high-surface-area hydrated lime.

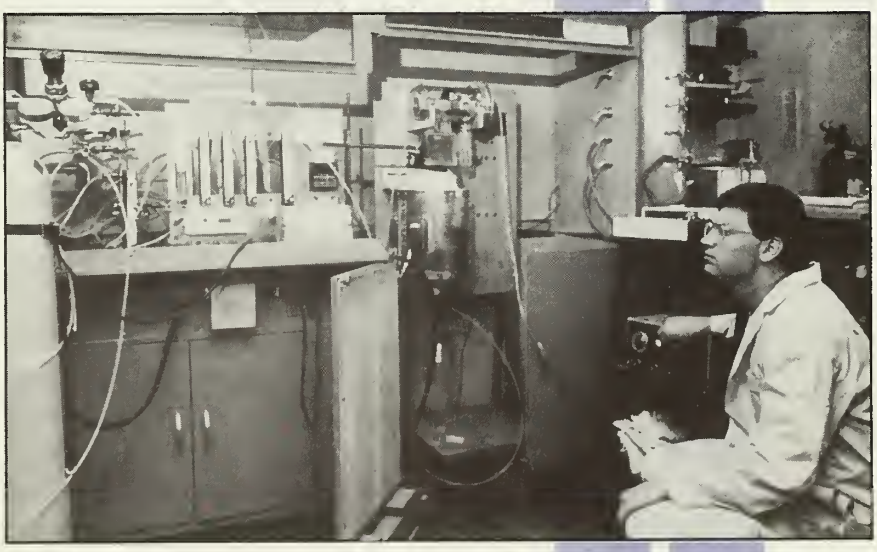
two to 20 pounds per hour. (A patented, one-step ethanol process also shows promise in the laboratory.) The second carbon monoxide effort with lignin produces a coal-like solid with less than 0.3 percent ash, essentially no pyritic sulfur, a higher volatile-matter content, and up to 20 percent less organic sulfur than coal. Other chemical cleaning methods being explored by the Survey include mild gasification which drives up to 60 percent of the organic sulfur from the char and extraction with a solvent that dissolves some of the sulfur.

For post-combustion cleaning, researchers are developing a high-surface-area (HSA) hydrated lime that will increase the effectiveness of dry-injection systems to remove sulfur dioxide from emissions at coal-burning power plants. Compared with other hydrates, the Geological Survey's HSA hydrated lime has achieved superior results in removing sulfur dioxide—up to 90 percent increased effectiveness, making dry-injection systems more effective for the state's coals.

To improve research capabilities, the ISGS established the Illinois Basin Coal Sample Program that provides identical samples of representative coals to scientists throughout the world, making possible the comparison of results from laboratory to laboratory and overcoming the problem of variable samples. One unique specimen contains naturally-labeled organic and pyritic sulfur—the pyritic form containing more sulfur-34 than the organic component. By using this sample, researchers can determine the source of the sulfur (organic or pyritic) in products produced by determining the sulfur-34 content.

These research programs are aimed at increasing the utilization of the state's coal and perhaps its limestone resources, preserving and expanding the market for Illinois' coal, ensuring clean air and national energy security, and continuing or even increasing employment of miners. For every

Dave Moran tests sulfur dioxide reactivity of high-surface-area hydrated lime in a Cahn Microbalance Reactor.



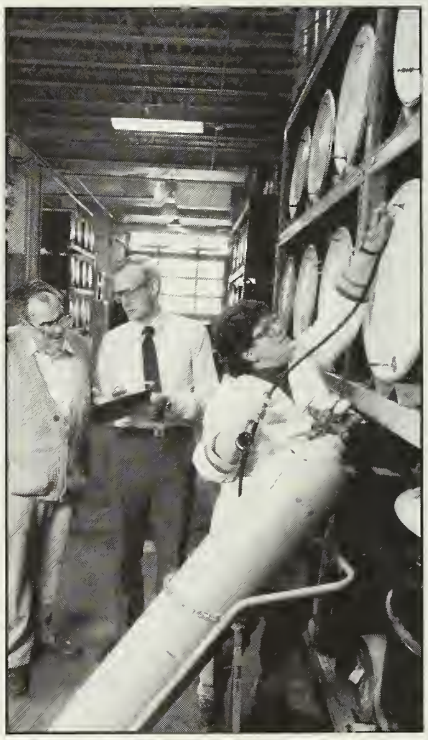
million tons of increased coal production, more than 200 mining jobs are created.

Even though coal has been studied at the Survey throughout its continuous 85-year history, much remains to be learned about this energy resource. For instance, how much of the state's 180 billion tons of coal can actually be developed?

Coal's availability studied

To assess the availability of Illinois' coal resources, the ISGS has undertaken a pilot study, sponsored by the USGS, within the Middletown 7.5-minute quadrangle, north of Springfield, containing seven coal seams. Scientists are looking at cultural features, the nature of overburden and interburden, coal thickness, stripping ratios, size of reserve blocks, and coal quality—major factors that may limit coal for mining, besides environmental and legal considerations. Plans call for evaluation of 20 to 25 such quadrangles, representing the range of mining conditions found in the state. The findings from each quadrangle will be extrapolated to areas with similar conditions throughout the state to estimate actual coal availability as opposed to estimates of coal as a resource.

Other coal-resource studies at the Survey include assessments of the Dekoven and Davis Coals in southeastern Illinois, where they have been mined, but their resources and reserves have not been systematically assessed, except where exposed at the surface and potentially surface minable. For Saline and Gallatin counties, the ISGS has generated maps showing overburden, exposed coal, oil fields, mined-out areas and reliability classes. Based upon calculations for coal resources made by new computer programs, in those two counties there are nearly 2.7 billion tons of Davis Coal and more than 1.7 billion tons of Dekoven Coal, representing a 1.3-billion-ton



Carl Kruse, senior research chemist, center, consults with Hank Ehrlinger, senior staff minerals engineer, about the Illinois Basin Coal Sample Program, while Joyce Hurley, technical assistant, checks the nitrogen atmosphere of the barrels which keeps the coal fresh.

increase over previous estimates of these coals for Saline and Gallatin counties

Supporting interstate cooperative research, the Kentucky, Indiana and Illinois State Geological Surveys compiled information on Springfield Coal in a computer data base, used to produce a base map showing state and county lines, limits of the Pennsylvanian, and outcrops of the coal, mines, channels, and faults; maps showing its thickness and depth; and maps showing the coal's sulfur and Btu content. Final versions of these maps are being prepared for public distribution.

For the USGS' National Coal Resources Data System, scientists compiled and correlated stratigraphic data for 529 coal test holes in FY89. During the current year, work continues on a minimum of 300 coal test holes with samples being collected and analyzed from four mines. These data are being entered into the Survey's data bases on coal quality and stratigraphy.

Up-to-date information on Illinois' mines is also available from the ISGS. Outlines of active mines have been revised to show the extent of mining as of January 1989. New county maps (1:100,000 scale) of these mined-out areas are now available. A new map format, depicting the extent of the mined areas relative to surface features, is based on the USGS' 7.5-minute quadrangle maps (1:24,000 scale) and includes color and line patterns that indicate the specific type of mining method used and information on the completeness of the source documents for each mine. This format is designed to consider the hazards of abandoned mines in land-use planning and development.

Marge Bargh, associate staff geologist, and Colin Trewogy, geologist, of the Coal Section, discuss aspects of the new county maps of mined-out areas.

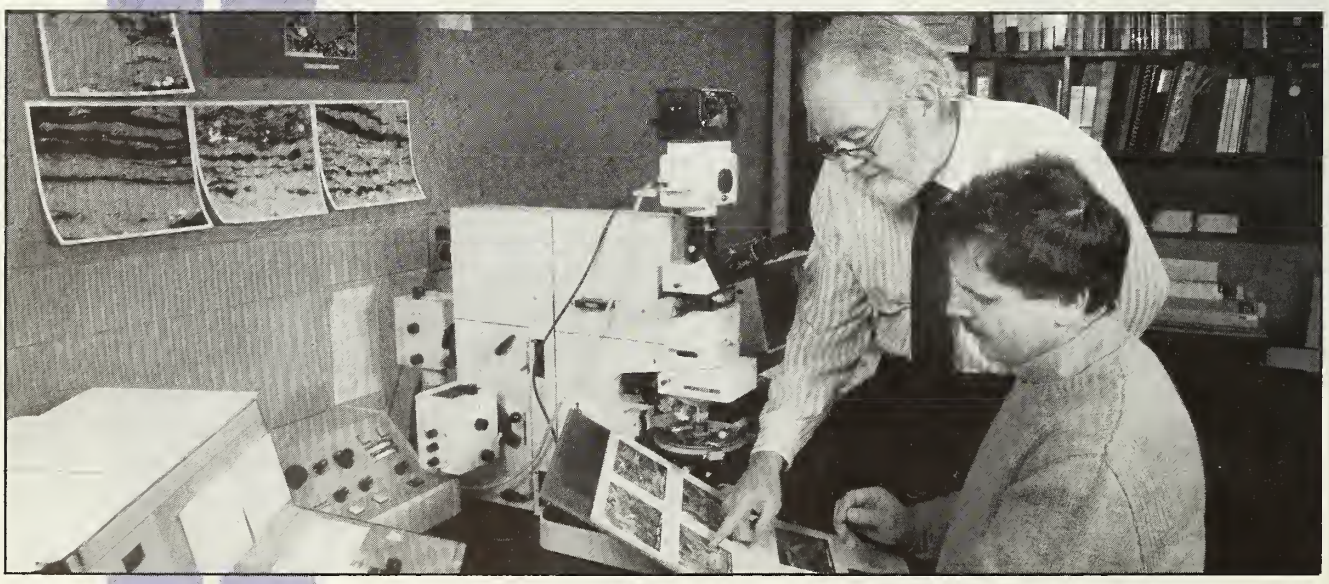
The ISGS is preparing a publication on coal exploration activities within the state from 1980 to 1989. Coal Test Hole Record and Plugging Affidavits will be computerized and the data base used to generate statistics and create coal exploration and development activity maps.

A cooperative study with the Department of Mining Engineering at Southern Illinois University-Carbondale, now in its third year, is aimed at characterizing ground conditions in underground coal mines and documenting how geologic and geotechnical information is used by the coal mining industry. A primary goal is to improve the predictability of unstable roof and floor sequences in advance of mining.

Other work on coal mining geology by the Survey's scientists included a report on the depositional environments of the Herrin Coal and immediate roof units at Crown II Mine, which was published April 1990 in a guidebook for the Central Section, Geological Society of America. Research has identified a new Energy Shale facies or shale type with a distinct geochemistry.

Distribution, variability important

To improve desulfurization processes, scientists require a knowledge of the distribution of organic sulfur and its variability. The Survey has developed a method to position an identified microscopic constituent (maceral) under the beam of the scanning electron microscope (SEM) and apply standardized procedures to determine the concentration of sulfur at spots where no mineral matter is present. This method is used to characterize organic sulfur in macerals adjacent to pyrite, both before and after charring the coal. Results showed that organic sulfur content increased near pyrite grains after the



Pictures of coal macerals, identified under the scanning electron microscope, are viewed by Dick Harvey, standing, senior geologist, and Ilham Demir, assistant geologist, Coal Section.

coals were charred at 550 degrees C., indicating that some pyritic sulfur released during charring is combined with the organic matrix rather than being emitted to the atmosphere. Sulfur-isotope data confirmed the movement of pyritic sulfur into the macerals during heat treatment of the coals....

Scientists analyzed residues from low-temperature ashing of nine special coals for their size distribution and noted significant variations in the size of minerals from one sample to another. The method has potential for predicting the fineness of crushing required to liberate mineral matter in coals.

Aiming at selected markets, staff members worked with ENR and leading development companies to apply integrated gasification combined cycle (IGCC) technology to the state's high-sulfur coal. At a Louisiana plant, the ISGS facilitated a successful 400-ton test of Illinois No. 6 coal that indicated decreased ammonia, higher Btu content, lower water requirement, and increased elemental sulfur production in comparison to results with western coal currently being used there.

Possibly extending the "life" of some coal mines in Williamson, Franklin and Saline counties, the Survey has tested several coal-mine gas wells for gas composition and flow rate. These wells were completed into abandoned and sealed coal mines, in which the remaining coal produces methane gas...a potentially significant resource.

Summing up the ISGS' work with energy, the state institution is seeking to enhance the wise use of Illinois' resources in environmentally acceptable ways. Scientists are pursuing ways to recover more of the remaining oil.... They are finding potential markets for the state's coal while working to meet new acid-rain-reduction goals through coal-cleaning and emission-reduction research well under way.... And throughout these efforts, researchers are learning more about the characteristics of these resources and their habitats which will help in their exploration and exploitation.

Although the Survey has focused most of its energy-related research and service programs on crude oil and coal--the first and second largest providers of the world's energy needs and two of Illinois' most abundant resources, there are other energy alternatives that need careful consideration. These include natural gas, compressed natural gas, nuclear energy, methanol, corn-derived ethanol, solar energy, wind power, and biomass (derived from fermenting wood and agricultural wastes).

There's no one answer to the energy issue. Wise decisions on the use of the state and nation's natural resources and their impact on the environment must only be made based on scientific and socio-economic knowledge. As the unbiased research arm of state government for the earth sciences, the Illinois State Geological Survey is working to keep options open--to utilize the state's resources, to help maintain Illinois' tax base, economy, and quality of life.

Research Projects in Fiscal Year 1990

The map of Illinois, printed on the following two pages, shows counties for which research results were published for Fiscal Year 1990 (June 1989-July 1990). For each of the three research groups—Mineral Resources and Engineering, Environmental Geology and Geochemistry, and General and Basic Research—programmatic areas have been identified and numbered in the map's legend.

To obtain complete coverage of the Survey's research and service efforts for the year or additional information about the various research projects being carried out across the state, please write or call the ISGS (217/333-4747) and request a copy of the Annual Report, which will be supplied free of charge. If you are interested in maps and other publications of the ISGS, request a copy of the "List of Publications," for which there is also no charge.

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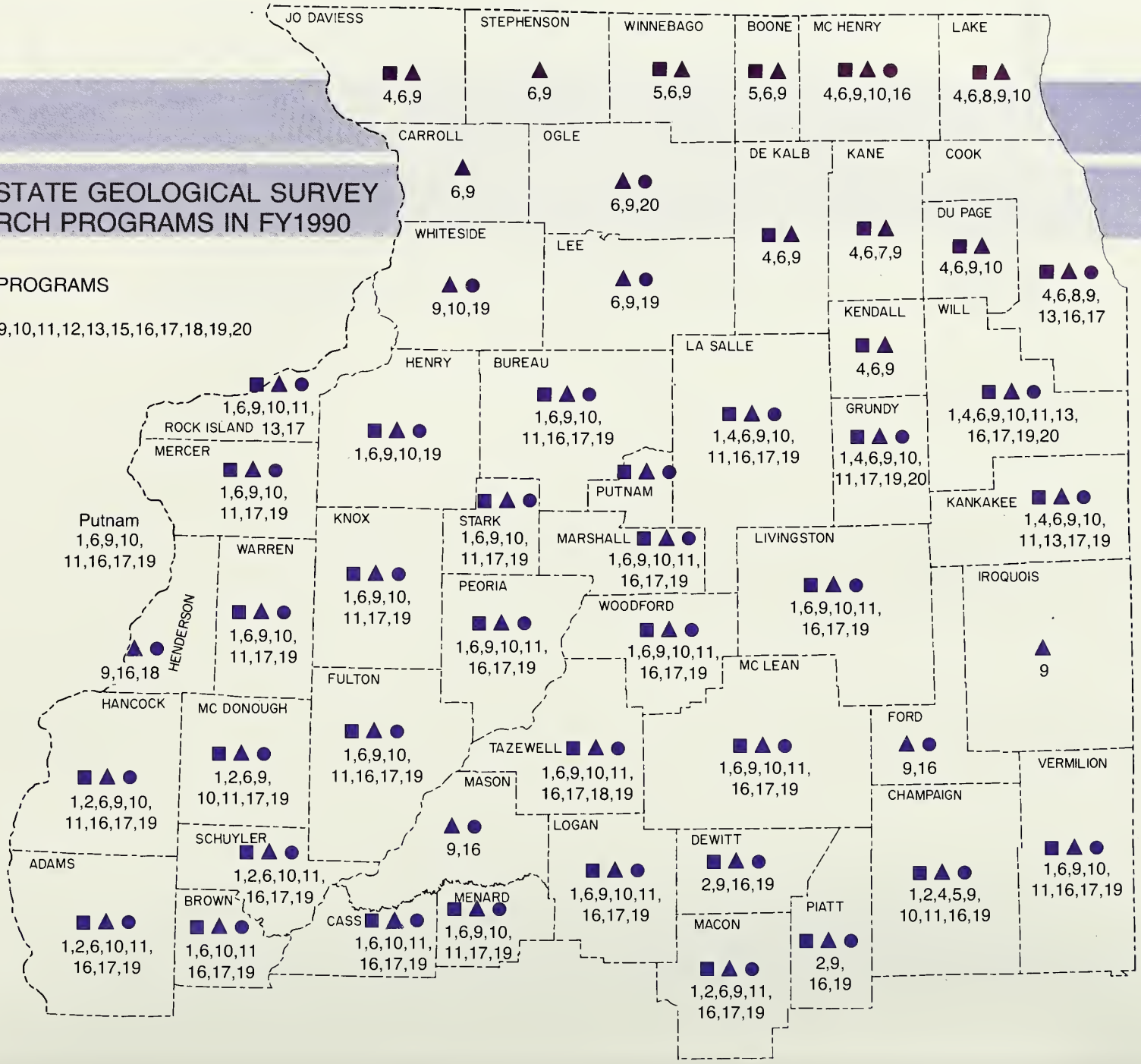
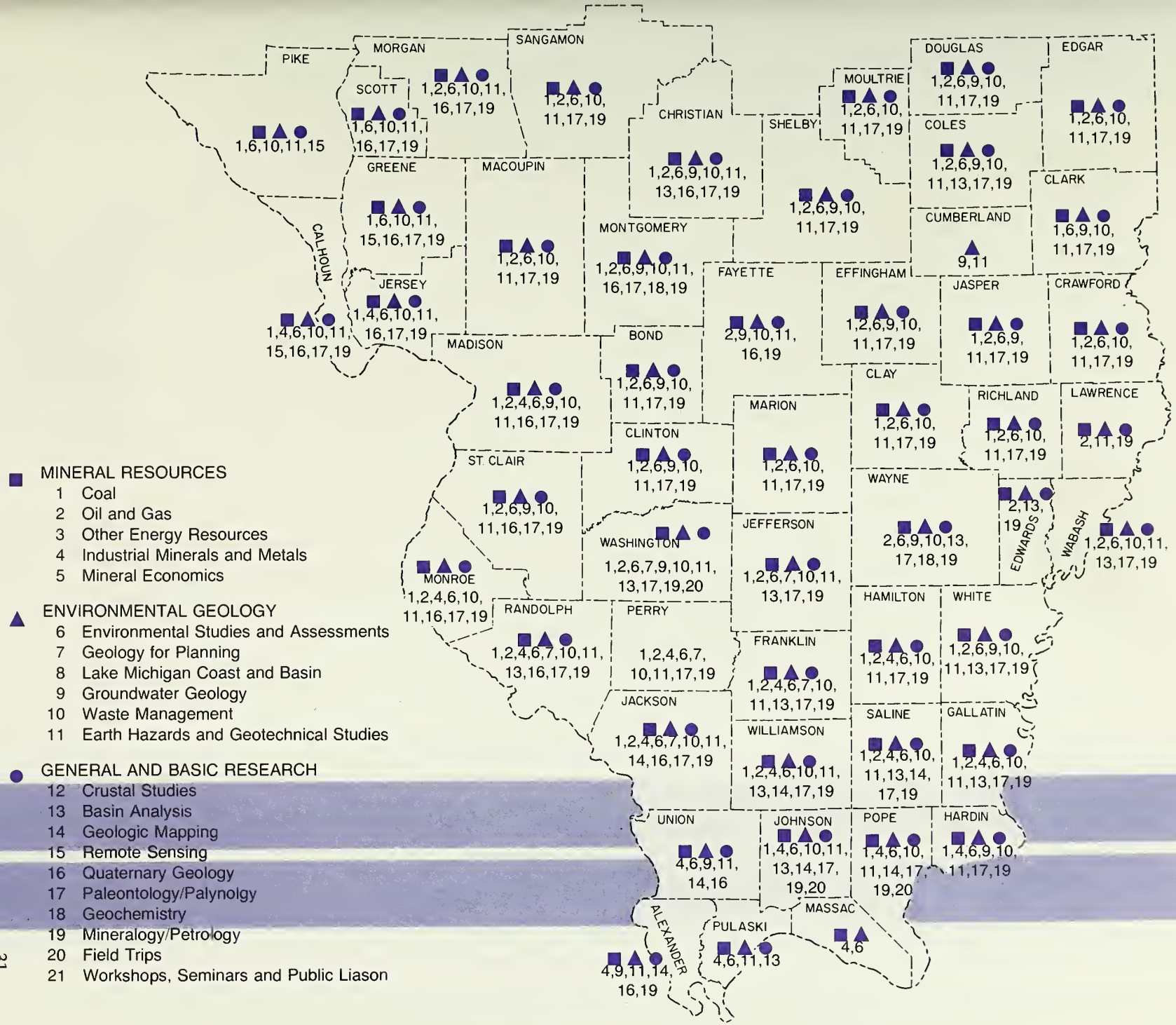
Champaign, Illinois 61820

ILLINOIS STATE GEOLOGICAL SURVEY RESEARCH PROGRAMS IN FY1990

STATEWIDE PROGRAMS

■▲● 2,4,5,9,10,11,12,13,15,16,17,18,19,20





- MINERAL RESOURCES
  - 1 Coal
  - 2 Oil and Gas
  - 3 Other Energy Resources
  - 4 Industrial Minerals and Metals
  - 5 Mineral Economics
- ENVIRONMENTAL GEOLOGY
  - 6 Environmental Studies and Assessments
  - 7 Geology for Planning
  - 8 Lake Michigan Coast and Basin
  - 9 Groundwater Geology
  - 10 Waste Management
  - 11 Earth Hazards and Geotechnical Studies
- GENERAL AND BASIC RESEARCH
  - 12 Crustal Studies
  - 13 Basin Analysis
  - 14 Geologic Mapping
  - 15 Remote Sensing
  - 16 Quaternary Geology
  - 17 Paleontology/Palynolgy
  - 18 Geochemistry
  - 19 Mineralogy/Petrology
  - 20 Field Trips
  - 21 Workshops, Seminars and Public Liason

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